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(19)

(54) COIL CONNECTOR

(71) We, RAYCHEM LIMITED, a British Company, of Rolls House, 7 Rolls Buildings, Fetter Lane, London, EC4, formerly of Moor House, London Wall, London. EC2Y 5HP, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:–

This invention relates to methods of making connections, especially electrical connections, and to devices for use in such methods.

Many attempts have been made to provide connectors for substrates such as, for example, electrical conductors, which do not require crimping or other mechanical deformation of the conductors. For example, in U.S. Patent No. 3 247 315 there is described a connector which comprises a tubular member capable of constricting, which consists of a piece of resilient sheet material which has been rolled to a tubular shape. In one embodiment the tubular member is retained in a radially expanded condition by means of an internal tube or plug of solder. In use, the connector is positioned about a pair of wires and heated so that the solder melts and the tubular member constricts, thereby gripping and holding the electrical conductors. This arrangement suffers from the disadvantage that the internal diameter of the tubular member is reduced by the presence of the solder tube or plug, and thus the tubular member is required to have a relatively large degree of resilient recovery to compensate for the thickness of the solder tube or plug.

British Patent No. 1 062 870 describes a heat-recoverable article in which the recoverable component is a resilient member in tubular form, the tube being circumferentially interrupted to permit changes in the radius thereof, and being retained in an expanded configuration by a fusible member which is positioned at least partly in the path of recovery of the recoverable member. When the fusible member is raised to a temperature at which it is insufficiently rigid to retain the resilient member in its expanded form, the recoverable member contracts and thereby urges at least some of the material of the fusible member in the direction of recovery. Such an article also requires a relatively large degree of recovery on the part of the resilient member to compensate for the thickness of the fusible member.

In forming terminations and splices in mineral insulated electric cables, it is desirable, and is becoming increasingly necessary in order to conform with official regulations, to provide an earth connection to the sheath of the cable. Mineral insulated electric cables consist of one or more conductors surrounded by a sheath, usually of copper or aluminium, and having insulation material comprising a powdered mineral, for example magnesium oxide. The terminations and splices are usually covered by a sleeve of heat-recoverable material to exclude moisture from the insulation material, for example as described in British Patent No. 1 098 304. It has been proposed in British Patent No. 1 428 134 to provide a device for both sealing and effecting an earth connection for a cut back end of a mineral insulated cable in which the earth connector is urged into contact with the copper sheath of the cable by means of the heat-recoverable sleeve. However such a connection is mechanically weak because the only force tending to retain the connector in contact with the sheath is the recovery force of the heat-recoverable sleeve. There is thus a need for an earth connector for a mineral insulated cable which does not require crimping (which might damage the insulation of the cable), which provides a strong mechanical contact with the sheath together with a low contact resistance, and which is small enough to be contained within the heat-recoverable sleeve used in terminating or splicing the cable.

U.S. Patent No. 3 355 202 discloses a terminating device for a linear body such as a fibrous glass cable, which device comprises a coil spring member secured therein but it is expressly stated in that Patent that the terminating device acts to secure itself to the fibrous glass cable by molecular adhesion and it is further expressly stated that no compressive forces are exerted by the device on the cable.

The present invention is based upon our observation that an especially effective and simple electrical connection to a line substrate can be made by using a radially shrinkable coil member as a connection device.

The present invention accordingly provides a method of forming an electrical connection to a

substrate, wherein the substrate is positioned within a dimensionally-recoverable article comprising a radially dimensionally-recoverable coil member, said article being in a temporarily dimensionally stable state (as hereinafter defined), and wherein the dimensionally-recoverable article is treated to allow said coil member to recover to form the connection, and there being no restraining member positioned in the direction of recovery between the article and the substrate.

By a "temporarily dimensionally stable state" there is herein meant that the article will not by itself exhibit dimensional recovery (in the absence of said treatment) and is not subject to any external mechanical forces which, if removed, would cause it to recover. That is to say, for example, the present invention does not contemplate the use (as described, for example, in British Patent Specification No. 889,207) of a coil spring which, immediately prior to its application to a substrate(s), is deformed by an externally applied force so that it is in an unwound or longitudinally compressed state, so that when the externally applied force is removed it shrinks radially to make the connection to the substrate(s). Rather, the present invention uses dimensionally-recoverable articles which are capable of remaining in a stable radially expanded state for an indefinite period (in the absence of said treatment), either by virtue of their own intrinsic heat-recoverable characteristics, as hereinafter described, or else by material positioned in the interstices of the coil member so as to prevent resilient recovery thereof, said material being disburdenable by said selective treatment when dimensional recovery is desired.

The present invention is especially suitable for connecting earth leads to the sheaths of mineral insulated cables and will, for convenience, from now on be described by reference to such an application. However, it will be appreciated that it is applicable to the formation of electrical connections to other line substrates, which need not, of course, be of circular cross-section.

In accordance with the present invention, the coil member is positioned about the cable in a radially expanded, but temporarily stable, form. For example the coil member may be formed from a heat-recoverable material. As is known, members made from heat-recoverable materials may be deformed from an original configuration and will retain the deformed configuration until they are heated, when they recover towards their original configuration. Amongst such materials there may be mentioned, for example, the polymers, such as cross-linked polyolefins described in U.S. Patents Nos. 2 027 962 and 3 086 242. These polymers may, if desired, be filled with conductive materials and/or be coated with a thin film of metal in order to make them electrically conductive.

More recently, certain metal alloys have been found to exhibit memory properties. Amongst such alloys there may be mentioned, for example, various alloys of titanium and nickel which are described, for example in U.S. Patents Nos. 3 174 851, 3 351 463, 3 753 700, 3 759 552, British Patents Nos 1 327 441 and 1 327 442 and NASA Publication SP 110, "55-Nitinol-The Alloy with a Memory, etc." (U.S. Government Printing Office, Washington, D.C. 1972). The property of heat-recoverability has not, however, been solely confined to such titanium-nickel alloys. Thus, for example, various beta-brass alloys have been demonstrated to exhibit this property in, e.g. N. Nakanishi et al, *Scripta Metallurgica 5*, 433-440 (Pergamon Press 1971) and such materials may be doped to lower their transition temperatures to cryogenic regimes by known techniques. Similarly, 304, stainless steels have been shown to enjoy such characteristics E. Enami *et al, id*, at pp, 663-68.

In general these metals have a transition temperature within the range of from −196°C to + 135°C, especially from −196°C to −70°C (this being the lowest temperature they are liable to encounter during everyday use), and thus may be brought into their martensitic state by immersion in liquid nitrogen.

However, more recently, it has been found possible to "precondition" memory metals so as transiently to raise their transition temperature. This enables the articles made from such alloys to be kept at room temperature prior to use, when they can be recovered by heating. Such preconditioning methods, which eliminate the need for liquid nitrogen during storage and transportation, are described, for example in German Applications OS 2 603 911 and OS 2 603 878.

In accordance with the present invention, the coil member may be made, for example, from a filled or coated heat-recoverable plastics material or, preferably, from a memory alloy such as a brass alloy and is placed in a radially expanded deformed configuration about the cable sheath. It is then warmed or allowed to warm so that it recovers and shrinks to grip the cable sheath. The earth lead is preferably formed as an integral part of the coil member.

It has previously been propsed in German Offenlegunsschrift 2 615 683 to form a heat-recoverable memory metal member in the form of a coil and it has also been proposed to use such a member as part of a device to form a connection between, for example, pipe lines. However, in accordance with the teachings of German Offenlegungsschrift 2 615 683 the heat-recoverable coil is positioned about a sleeve which separates the coil from the substrate and acts to restrain the recovery of the coil. There is no suggestion of using the coil member *per se* to form an electrical connection as in accordance with the present invention.

In other preferred forms of the present

invention the coil member may be made from a resilient material and may be held in a radially expanded configuration by a fusible, chemically degradable or frangible material disposed within the interstices of the coil.

Reference is made in this respect to British Patent Application No. 2832/77 Serial No. 1 599 998 filed 24th January, 1977, which describes and claims resiliently recoverable connectors which are held in a dimensionally unstable state by means of keepers. As is set out in that application, the disclosures of which are incorporated herein by reference, the keeper may, for example, be made from a fusible or heat-softenable material such as a thermoplastic polymer or a low-melting alloy or from a pyrolysable material or from a material which weakens or changes shape when subjected to chemical treatment, including, for example, various plastics materials such as polycarbonates which disintegrate by stress cracking when treated with certain solvents, and other soluble materials. All these materials may be employed to hold out a resilient coil member in accordance with the present invention. In other cases the material may simply be one which can be mechanically broken or dislodged when connection is required.

In an especially preferred form of the present invention, the coil member is made of resilient material, e.g. beryllium-copper, and is "held out" in a radially expanded deformed configuration by embedding it in a fusible material, preferably solder, the fusible material being positioned between turns of the coil member. In use the coil member is placed in position about the cable sheath and is then heated. Upon heating the fusible material melts and the resilient coil member is allowed to contract radially and grip the sheath. The use of solder as the fusible material enhances the electrical characteristics of the resultant connection. If desired the fusible material could be replaced by a material which softens or weakens on other treatment, for example, a soluble material.

Preferably the fusible or heat-softenable material is solder, which preferably has a melting point of from 40° to 100°C.

One form of connector, suitable for use in the present invention and the manufacture thereof, will now be described in more detail by way of example only with reference to Figures 1a to 1e of the accompanying drawings which show various stages in the manufacture of the coil member.

A helical coil spring 1, having an earth lead 2 integrally attached thereto, is radially expanded by counter rotating the ends of the coil, and placed on a PTFE mandrel 3. The mandrel, carrying the coil spring, is then dipped in a bath of low melting point solder so that the solder 4 fills the interstices between adjacent turns of the coil. After the solder has cooled the coil is removed from the mandrel, and it is found that the solder prevents the coil from contracting radially.

In use the connector is positioned about a cable sheath and heated to melt the solder, whereupon the coil recovers and firmly grips the cable sheath.

Certain advantages flow from the use of the preferred embodiments of the invention. By using a fusible material positioned in the interstices between adjacent terms of the coil member it is possible to utilise substantially all of the radial recovery of the coil member. The coil member can also, in most cases, be radially expanded to accommodate a wide variety of cable sheath sizes without stressing the material of the coil member beyond its elastic limit. Furthermore, it is found in practice that on recovery individual turns of the coil member tend to adjust themselves independently so as to conform to any minor irregularities in the surface of the cable sheath.

Other variations and modifications falling within the csope of the present invention will be apparent to those skilled in the art.

WHAT WE CLAIM IS:—

1. A method of forming an electrical connection to a substrate, wherein the substrate is positioned within a dimensionally-recoverable article comprising a radially dimensionally-recoverable coil member, said article being in a temporarily dimensionally stable state (as hereinbefore defined), and wherein the dimensionally-recoverable article is treated to allow said coil member to recover to form the connection, and there being no restraining member positioned in the direction of recovery between the article and the substrate.

2. A method as claimed in Claim 1, wherein the coil member is formed from a heat-recoverable material.

3. A method as claimed in Claim 2, wherein the coil member is formed from a memory metal.

4. A method as claimed in Claim 3, wherein the memory metal is a brass alloy.

5. A method as claimed in Claim 1, wherein the coil member is made from a resilient material and is held in a radially expanded configuration by a heat-fusible, heat-softenable, chemically degradable or frangible material disposed within the interstices of the coil.

6. A method as claimed in Claim 5, wherein the resilient material is beryllium-copper.

7. A method as claimed in Claim 5 or Claim 6, wherein the coil member is held out by solder.

8. A method as claimed in any one of Claims 1 to 7, wherein the connection is made between an earth lead and the sheath of a mineral insulated cable.

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1599997 COMPLETE SPECIFICATION

1 SHEET This drawing is a reproduction of the Original on a reduced scale

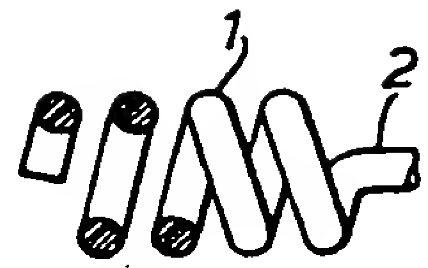

FIG. 1a.

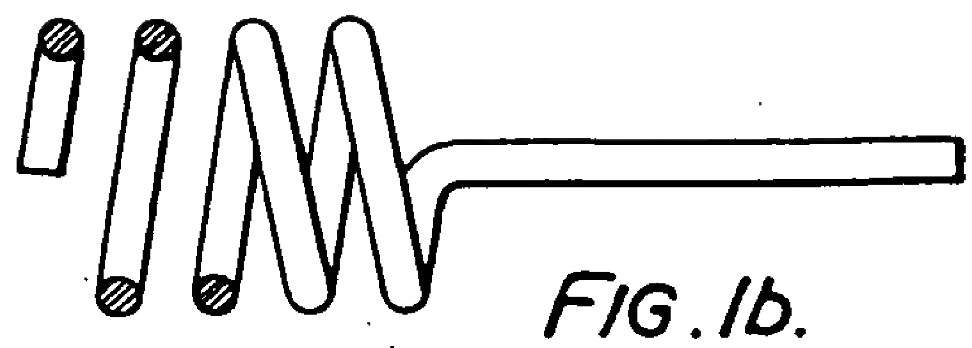

FIG. 1b.

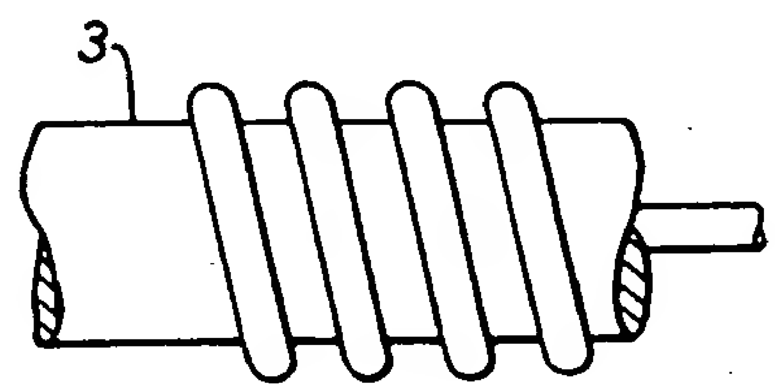

FIG. 1c.

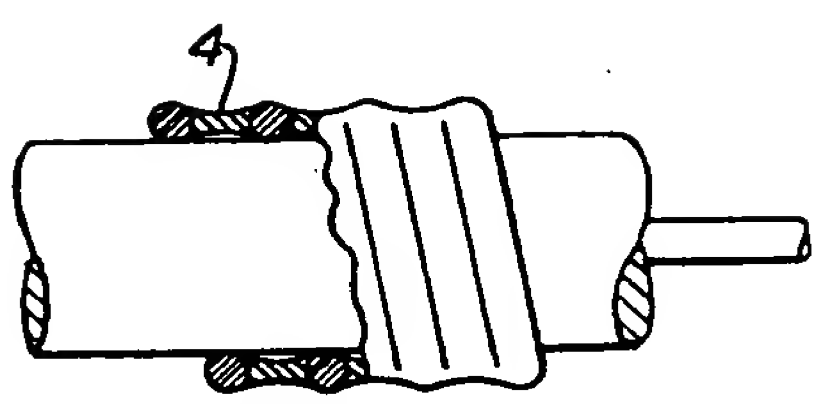

FIG. 1d.

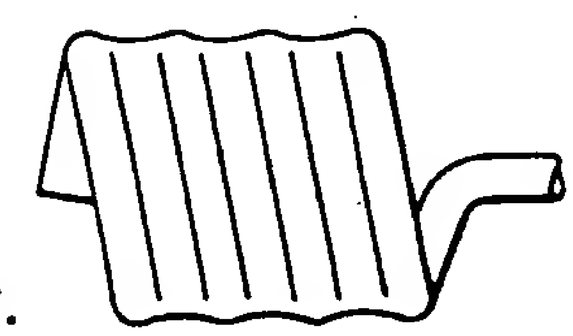

FIG. 1e.